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## 3-D Displays and Controls for Sonar Operators

*Advances in human-computer interface technology enable improved display and computer control.*

### DAVID ROUSSEAU

*Advanced Technology  
ASW Displays Project  
Navy Command, Control, and Ocean  
Surveillance Center  
Research, Development, Test and  
Evaluation Division  
San Diego, Calif.*

The next generation of human-computer interface technology is rapidly evolving to permit a new way of displaying information and controlling computers.

- The increasing speed and decreasing cost of high-resolution graphics computers is making it practical to generate complex imagery with acceptable detail in real time.

- Small high-resolution monochrome cathode ray tubes (CRTs) have long been used for military helmet-mounted displays (HMDs). These are presently among the high-

est resolution displays used in HMDs. Full color CRT-based systems are just now becoming commercially available, and color liquid-crystal displays (LCDs) with acceptable resolution should be available by mid-decade. Both types of displays are already finding their way into commercial stereoscopic HMD systems.

- Commercial versions of electromagnetic and infrared (IR) six-degree-of-freedom (6-DOF) position sensors were originally developed for military head-trackers that control aircraft sensors and weapons. These, and ultrasonic, systems are now becoming increasingly affordable. Their use has also been expanded to create various three-dimensional (3-D) haptic controllers.

- Automatic speech recognition systems have been under development for years and are finally becoming fast and robust enough for serious applications. Speech recognition systems have evolved into continuous-speech and discrete-word versions.

The continuous speech systems must be extensively "trained" by each user in order to successfully function. The discrete-word versions require much less training and can accommodate a wider spectrum of individuals, but the speaker must deliberately insert short pauses between each word spoken. There is one exception to this dichotomy, however. For the last few years, BB&N has been working under Defense Advanced Research Projects Agency (DARPA—recently renamed ARPA to increase its non-defense technology development efforts) funding to develop a speaker independent continuous-speech recognition system. They have developed a software package that is presently undergoing beta-testing on Silicon Graphics INDIGO computers. Recent demonstrations have shown very good results. [Ed. note: Although orthogonal in principle, continuous speech, speaker-independence, and large vocabulary size all make the recognition task more challenging. For more on speech recognition and VR, see the Thomas & Stuart article in

*Virtual Reality Systems Vol. 1, No. 1.]*

- Two methods of performing eye-tracking are prevalent and commercially available. The most common method uses IR light and IR video cameras that monitor the eye. The orientation, or "look- vector," of the eye is computed from the relative positions of the digitized video imagery of the pupil and Purkinje reflection. A newer technique to reach the commercial market uses computers to monitor the neural impulses from the muscles that control eye movement. This system, called "electro-oculography," is like a localized electroencephalogram (EEG) that uses simple contacts around the brow, temple and cheek to detect the activity of the eye-control muscles.

Finally, the newest technology on the scene is digitally modified sound that presents the operator with 3-D binaural hearing via headphones. This system modulates the frequency, amplitude and timing of sound so that it is altered in the same way that it would have been if the listener had actually heard it coming from the desired location. The computer processes sound through digital signal processors executing equations that are empirically determined and which replicate the acoustic effects of the shape of the outer ear. This system is based on university and NASA research which leads directly to a commercial product that can present multiple channels of realistic 3-D audio.

These technologies are being studied, individually and collectively, for their application to tactical Naval operations at the Navy Command, Control and Ocean Surveillance Center (NCCOSC) Research, Development, Test and Evaluation Division in San Diego. Many of today's Virtual Reality applications

don't require all these technologies to be successful, but some applications do. Anti-submarine warfare (ASW) is one application area that will require the best of all these.

## Discussion

It is known that performance with displays improves when operator workload is reduced, and that this effect is amplified by prolonged operations. Therefore, displays which minimize this work load result in reduced errors and fatigue, improved operator speed, and improved decision making. This requires displays that present information in ways which take maximum advantage of natural human perceptual and cognitive skills. Few display systems in use today are more abstract than those used to support the ASW mission area.

Sonar displays have not changed significantly for several years. Existing ASW displays present information that is altered, deleted, or sim-

plified due to the physical limitations of the display devices themselves. All sonar information is presented on monochrome computer screens controlled by a host of variable function keys. The sonar data presented on any given display is chosen from one horizontal "Slice" of the sensor data. Passive sonar data is displayed in bearing vs. time format, while active data is presented in bearing vs. range format. There is no map of the ocean on the screen for reference, and the sonar operator can only listen to one beam of the sonar at a time. Watch Jonesy do his job in *The Hunt for Red October* to get a glimpse of what it's like. Diverse sources of information must be correlated by the sonar operator, who then creates a mental model of the multi-dimensional ASW environment. The majority of this mental image must be derived from multi-dimensional acoustic, physical, and temporal information that has been presented in a very abstract visual two-dimensional (2-D) format (Figure

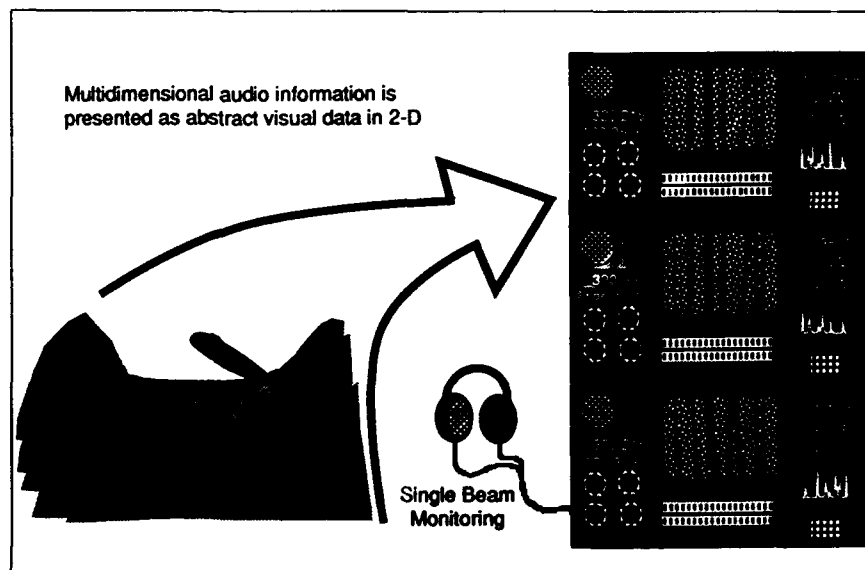
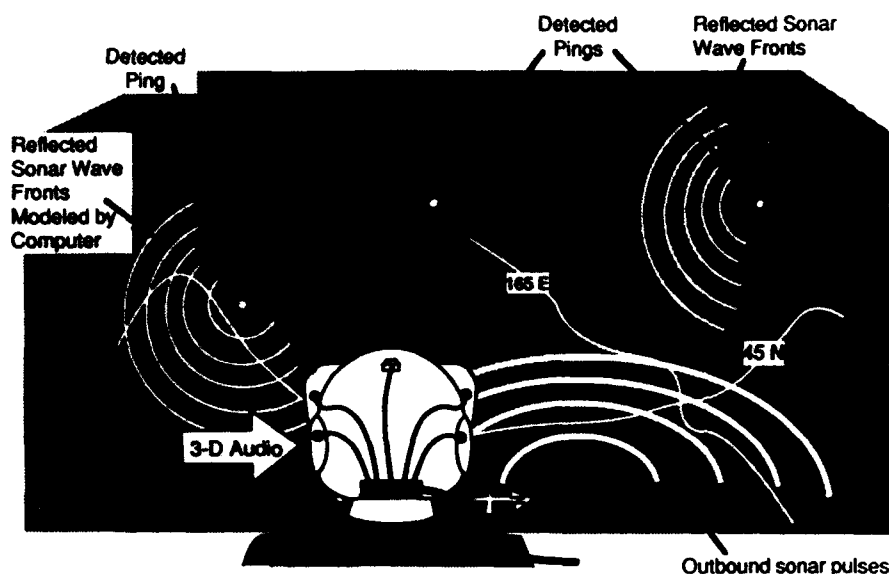


Figure 1. Today's method—Multidimensional audio information is presented as abstract visual data in 2-D.



**Figure 2.** Real-time Active Propagation Display.

1). This method of presenting complex, cross-sensory, multi-dimensional information on abstract 2-D displays may be enhanced with the data from the ship's sensors.

The application of new 3-D visual and audio display technologies to the ASW problem could yield significant improvements in operator performance and operational effectiveness. A virtual 3-D sonar display system could present the critical tactical information in a far more intuitive and integrated way, thereby reducing the cognitive interpretation burden and learning time, while improving the tactical success rate over current systems.

Such an advanced technology ASW display system could consist of:

1) the application of 3-D, stereoscopic, high-resolution, color displays in an HMD or boom-mounted (periscope-like) system,

2) a 3-D position tracker (for the

HMD),

3) 6-DOF manipulators integrated with speech recognition and eye tracking for computer function control,

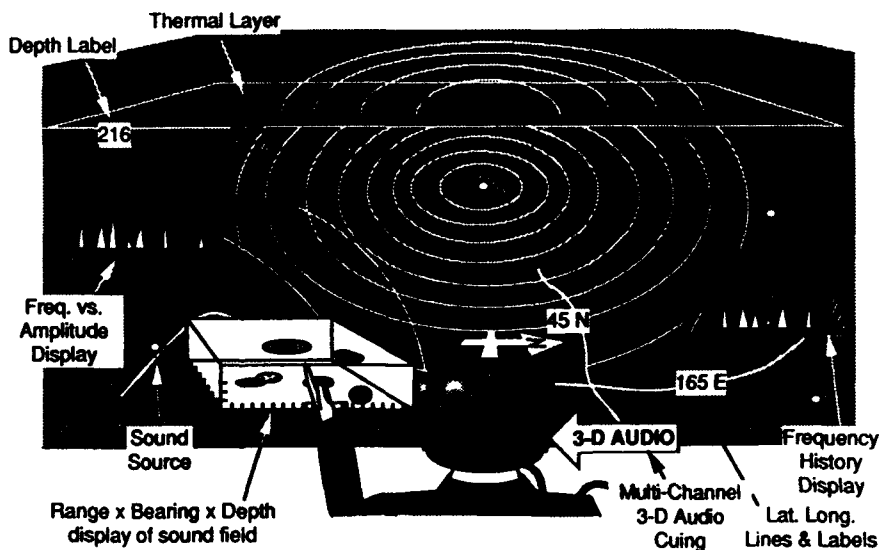
4) the incorporation of 3-D audio

for presentation of multiple beams from the sonar to provide intuitive cuing, and for correlation of acoustic transients and active returns to the ocean environment, and

5) the intuitive depiction of high-resolution computer-generated imagery of the ASW environment based on the display of active, passive, location, and environmental sensor information integrated with the local bottom topography database.

The exact nature of the displays that may prove most effective is yet to be determined, but speculation unfettered by display constraints leads to some intriguing possibilities.

For example, in the active sonar mode the 3-D ASW display could provide the sonar operator with a 360-degree field-of-regard image of the ocean bottom topography and water properties integrated with wave fronts representing the propagation of the sonar pulses (Figure 2). The operator would see these wave fronts being reflected off the local



**Figure 3.** Possible real-time 3-D passive ASW Display.

# AEROSPACE & MILITARY APPLICATIONS

topography and all known obstacles in the data base, and refracted by the model of the local water properties. The operator would therefore be able to see which returns are from known obstructions and compare that with the imagery of actual returns received by the sonar. The operator would then be able to point to sonar contacts, or designate them by simply looking at each one and telling the computer what action to take to classify and label each contact. Integrating this 3-D visual representation with acoustic analysis and cuing from the 3-D audio system would give the operator an intuitive picture of the active ASW environment.

Similarly, in the passive sonar mode the operator would be able to look around at real time noise sources with cuing from the 3-D audio system (Figure 3). The sonar operator could also view the passive sensor history over a desired time span for all bearings and elevations in a single 3-D volume (Figure 4). In each case any sonar beam could then be selected for analysis by voice command related to haptic or eye-tracked designation.

Similar display approaches could be adapted for fixed-site ASW facilities. Application of such a display system to airborne ASW is more challenging due to the strict size, weight, and safety constraints of ASW aircraft. Computer size and weight are constantly decreasing, however, and helmet weight and umbilical connections can be engineered for aircraft safety. Many of the displays developed for surface ASW would be directly applicable to both airborne and ashore ASW. A few specialized displays may be added for such things as sonobuoy coverage, however (Figure 5). Significant enhancements to total system effectiveness could result from the addition of a

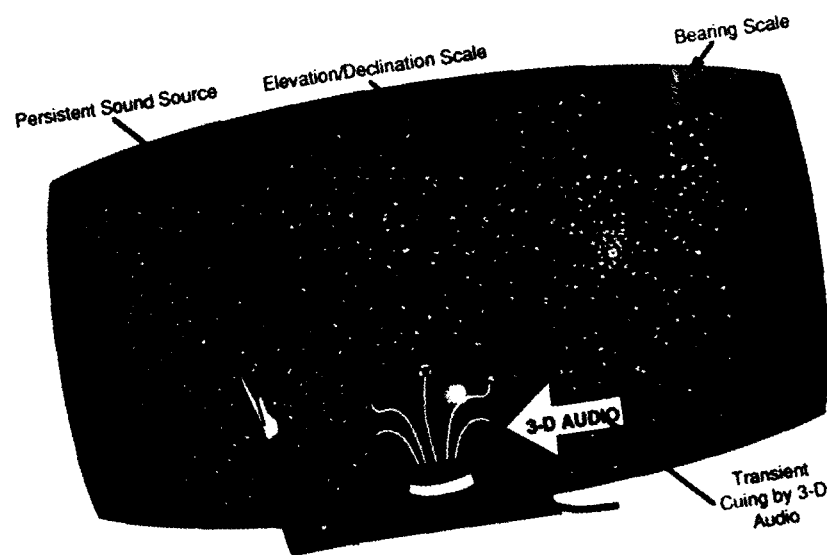


Figure 4. Passive sonar display, showing bearing, elevation/declination, and time history in 3-D.

virtual ASW display system, without redesign of other system components (e.g., sensors and sources of self-noise).

As this research continues, new methods for presenting ASW information could arise that would make

data relationships more apparent, increase situational awareness and enhance the quality of operator problem-solving. This, in turn, may enable development of more sophisticated and effective tactics. Certainly, current tasks of target detection, localization, and classification would

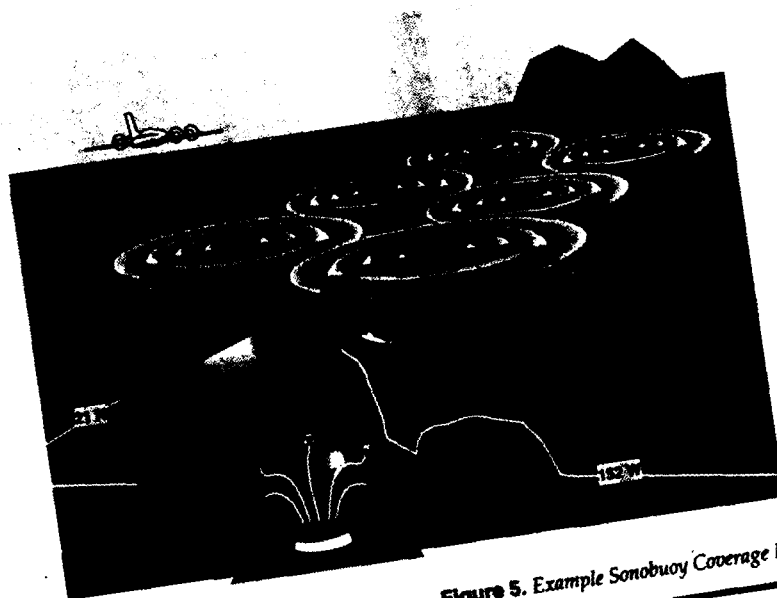


Figure 5. Example Sonobuoy Coverage Display.

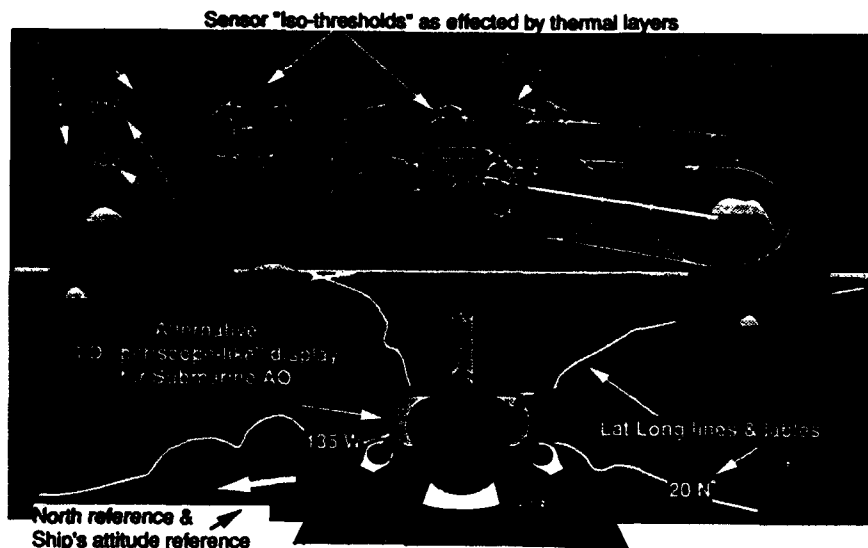


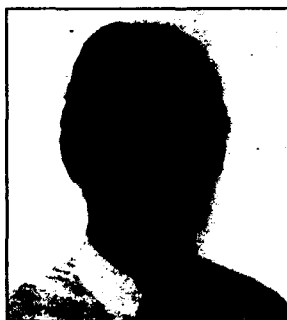
Figure 6. Potential submarine approach officer display.

improve. Reductions in operator training and increases in retention could also be significant, and the effectiveness of each sonar operator could be multiplied as well.

This technology could also be applied effectively to ASW tactical support by providing the shipboard ASW officer (or submarine approach officer) (Figure 6) with a 3-D image of the ocean environment, his weapons engagement envelopes, sensor coverage volumes, and the hostile submarines that have been identified.

These technologies are already being applied to numerous civilian tasks, including architecture; mechanical design in the automotive and aerospace industries; pharmaceuticals research; medical imagery for 3-D display of CAT scan, NMR, and ultrasonic medical data; education, and functional aids for the handicapped. If these new technologies are applied to the tactical naval environment, their impact on operational effectiveness could be dramatic, and their impact on training methods and systems may be equally dramatic.

History has taught us that the requirement to operate a global navy will not diminish at a rate commensurate with the decrease in our assets. The sale of Chinese and formerly Soviet submarines to Third World countries continues because of the economic and political needs of those nations. Our budgets, ship inventories, and manpower levels will probably continue to decrease over the next decade or beyond, for similar reasons.



**David Rousseau** received his B.S. in Aeronautical Engineering from the University of California, Davis in 1975. He was an engineer in the Aviation and Surface Effects Department at the Naval Ship Research and Development Center in Bethesda, Md. from 1976 to 1987, where he worked on Wing-in-Ground-Effect vehicle research and development, and also served as their primary ground-effects vehicle test pilot. Rousseau also spent two years as a technical advisor on the CINCPACFLT staff in Pearl Harbor, Hawaii, under the Navy Science Assistance Program. He is currently heading the Advanced Technology ASW Displays project to study the application of Virtual Reality to tactical anti-submarine warfare.

Therefore the workload for each person will increase, and the tactical cost of losing one platform out of a reduced inventory will be magnified. Systems that can improve operational performance while requiring lower manning and less training will be critical, and those systems that can achieve the greatest performance improvements at the lowest cost will be essential. □

## For More Information

Contact David Rousseau: Naval Command, Control and Ocean Surveillance Center/Research, Development, Test and Evaluation Division/San Diego, Calif. 92152-5000.